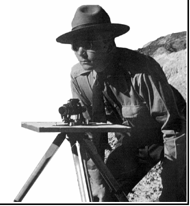
GEOLOGIC RESOURCE MONITORING PARAMETERS

Seismicity



BRIEF DESCRIPTION: Shallow-focus earthquakes (those with sources within a few tens of kms of the Earth's surface) are caused by crustal movements along strike-slip, normal and thrust faults, though they can also be induced anthropogenically. They can result in marked temporary or permanent changes in the landscape, depending on the magnitude of the earthquake, the location of its epicenter, and local soil and rock conditions [see surface displacement]. Deep-focus earthquakes (below about 70 km), unless of the highest magnitude, are unlikely to have serious surface manifestations.

To avoid, reduce or warn of environmental impacts, it is necessary to know the size, location, and frequency of seismic events. These parameters can identify active faults and the sense of motion along them. Also of great importance is the spatial pattern of seismicity, including the presence of seismic gaps, and the relationship to known faults and active volcanoes. At least three, and generally many more, monitoring sites are required to determine the necessary parameters.

Seismic observations constitute one of the oldest forms of systematic earth monitoring (geoindicators). There are now in operation many national, regional and international seismic networks, which provide information about the location, size and motion of earthquakes anywhere in the world. However, shallow-focus tremors of lower magnitude, may not be detected by these means, and must be monitored more closely, on a local basis. Seismic hazard maps can be constructed to identify areas at varying risk from earthquake damage.

Significance: Earthquakes constitute one of the greatest natural hazards to human society. Between 1960 and 1990 earthquakes killed about 439,000 people worldwide and caused an overall economic loss of some $US 65 billion. The 1994 Northridge earthquake in California alone resulted in over US$30 billion in property damage, and the 1995 Kobe earthquake over $100 billion. Surface effects include uplift or subsidence, surface faulting, landslides and debris flows, liquefaction, ground shaking, and tsunamis (‘tidal’ waves caused by undersea tremors). Damage to buildings, roads, sewers, gas and water lines, power and telephone systems, and other built structures commonly occurs.

Environment where Applicable: Any area of active tectonics or weakness in old cratons, or where human activities change subsurface rock pressures.

Types of Monitoring Sites: Remote, away from obvious sources of ground shaking, such as traffic, mines, quarries, and heavy industry. For heavily populated areas in seismically-active areas, a dense array of seismographs is recommended.

Method of Measurement: Standard seismographs. These should be able to record three components of ground acceleration with a dynamic range of 10-5 to 1 g (acceleration due to gravity) in the frequency band 0.1 to 20.0 Hz, maintaining absolute time to a precision of 5 ms. Monitoring seismicity induced by mining or fluid extraction activities generally requires networks of closely-spaced (<5 km) instruments that can record considerably higher frequencies (20-1500 Hz) than for natural seismicity. Seismic data should be transmitted quickly (preferably in real time) to central analysis units. The effects of increases in crustal stress, which can be released through earthquakes, is becoming increasingly important as a tool for estimating seismic hazard. Stress increase may be detected indirectly in many ways, for example by monitoring actual earth stress in mines and boreholes, magnetic, gravity and electric fields, water levels in wells, surface deformation (creep, tilt, extension or shortening). However, these are not a substitute for direct observations of seismicity using seismographs.

Frequency of Measurement: continuous

Limitations of Data and Monitoring: Monitoring seismicity will identify where earthquakes are likely to occur and their potential magnitude, but not when they might be expected.

Possible Thresholds: A threshold is reached when natural or induced stresses overcome the strength (resistance to failure) of a rock mass and rupture occurs, expressed as an earthquake. Several scales of earthquake magnitude are in common use, based on their surface effects. Near-surface tremors with magnitudes <5 may be felt, but are rarely damaging. Those >M5 can induce significant damage. Earthquakes above M7 can be expected to have severe environmental and human impacts.

Key References:

Bolt, B.A. 1993. Earthquakes, New York: W.H. Freeman.

McGuire, R.K. (ed.) 1993. The practice of earthquake hazard assessment. International Association of Seismology and Physics of the Earth's Interior.

National Research Council 1991. Real-time earthquake monitoring: early warning and rapid response. US National Academy Press, Washington.

Related Environmental and Geological Issues: Near-surface earthquakes can induce a wide range of important and generally irreversible changes in landscape morphology: including faults and surface fissure [see surface displacement], sand-soil liquefaction, rockfalls, debris flows and other forms of slope failure [see slope failure (landslides)]. Human activities such as constructing dams and reservoirs, pumping out or in waste fluids, hydrocarbons and water can trigger seismic activity in normally aseismic (‘quiet’) areas. The social and economic impacts of major earthquakes can be devastating, particularly in urban areas. A proper building code that sets standards for construction and maintenance should be based on knowledge of both seismicity and local ground conditions.

Overall Assessment: It is essential to monitor the seismicity of any tectonically active area so as to avoid or minimize injury to life and damage to property.

Source: This summary of monitoring parameters has been adapted from the Geoindicator Checklist developed by the International Union of Geological Sciences through its Commission on Geological Sciences for Environmental Planning. Geoindicators include 27 earth system processes and phenomena that are liable to change in less than a century in magnitude, direction, or rate to an extent that may be significant for environmental sustainability and ecological health. Geoindicators were developed as tools to assist in integrated assessments of natural environments and ecosystems, as well as for state-of-the-environment reporting. Some general references useful for many geoindicators are listed here:

Berger, A.R. & W.J.Iams (eds.) 1996. Geoindicators: assessing rapid environmental change in earth systems. Rotterdam: Balkema. The scientific and policy background to geoindicators, including the first formal publication of the geoindicator checklist.

Goudie, A. 1990. Geomorphological techniques. Second Edition. London: Allen & Unwin. A comprehensive review of techniques that have been employed in studies of drainage basins, rivers, hillslopes, glaciers and other landforms.

Gregory, K.J. & D.E.Walling (eds) 1987. Human activity and environmental processes. New York: John Wiley. Precipitation; hydrological, coastal and ocean processes; lacustrine systems; slopes and weathering; river channels; permafrost; land subsidence; soil profiles, erosion and conservation; impacts on vegetation and animals; desertification.

Nuhfer, E.B., R.J.Proctor & P.H.Moser 1993. The citizens' guide to geologic hazards. American Institute for Professional Geologists (7828 Vance Drive, Ste 103, Arvada CO 80003, USA). A very useful summary of a wide range of natural hazards.